

NOAA Southwest Fisheries Science Center

Strategic Science Plan

Executive Summary

The Southwest Fisheries Science Center (SWFSC) is the research arm of NOAA's National Marine Fisheries Service (NMFS) in the Southwest Region. The SWFSC generates the science necessary to manage and conserve the living marine resources of the California Current, the eastern tropical Pacific, and portions of the California watershed ecosystems, the North Pacific, Pacific Islands, and Southern Ocean. These regions span millions of square kilometers, include a diverse range of coastal, shelf, and oceanic environments, and support important commercial and recreational fisheries, a wide variety of recreational activities, and endemic (native/indigenous) and transboundary threatened and endangered living marine resources.

Public needs and expectations associated with these ocean ecosystems are diverse and form a set of drivers that are the basis for the SWFSC's scientific research. The SWFSC generates and disseminates the scientific basis needed to fulfill these expectations. Research is authorized by the Magnuson-Stevens Fishery Conservation and Management Act, the Marine Mammal Protection Act, the Endangered Species Act, and the U.S. Antarctic Marine Living Resources Convention Act, as well as various international treaties and agreements. The SWFSC's research is directly responsive to NMFS Headquarters, the West Coast Regional Office, Pacific Fishery Management Council, State of California, Scientific Review Groups, and the U.S. delegations to international regional fishery management organizations and international treaties.

The scope of SWFSC's research is diverse and scientifically challenging. The California Current, a cold, eastern boundary current, is characterized by seasonal upwelling, a narrow continental shelf, low and variable freshwater input, and exceptional interannual oceanographic variability heavily influenced by the El Niño-Southern Oscillation. Many of its commercially significant fisheries experience boom-bust population cycles and, in the case of salmon, large-scale artificial propagation. In addition to commercial fisheries interests, there are significant recreational and non-extractive users of the ecosystem as well as disparate needs of constituents for fresh water, resulting in impacts on habitat for anadromous and estuary-dependent species. The SWFSC, together with the Northwest Fisheries Science Center (NWFSC), provides the scientific knowledge to inform management decisions on the stewardship of the California Current Large Marine Ecosystem (CCLME). Equally important to the SWFSC's scope is research conducted in tropical (eastern tropical Pacific) and polar

(Southern Ocean) ecosystems involving a large international stakeholder component and multi-national agreements and conventions, and a significant transboundary component of the living marine resources for which the SWFSC is responsible.

This Strategic Science Plan represents the SWFSC's research plan for the next 5 years and is organized around the following research themes:

Theme 1. Population assessment: Provide assessments and management advice to rebuild and sustain fisheries, fishing communities, protected species, and their ecosystems

Theme 2. Ecosystem analysis: Assess and predict how environmental changes and human activities affect ecosystems and design and implement new management paradigms to manage fisheries and recover protected species

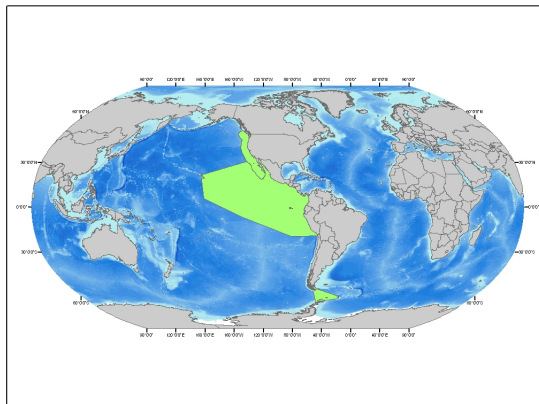
Theme 3. Observations, measurements and surveys: Provide information and data to support population assessments and analyses of ecosystem variability and change

Theme 4. Technological innovation and development: Improve ecosystem observations and survey methodologies through a variety of advanced technologies and sensor development

An Implementation Plan will accompany this Strategic Science Plan, and will outline the procedures for resource allocation, decision-making, and communication to accomplish core activities and high priority research. Although separate documents, the Implementation Plan and Strategic Plan work together as guiding documents for the SWFSC's mission and research activities.

Background and Purpose

The Southwest Fisheries Science Center (SWFSC) is the research arm of NOAA's National Marine Fisheries Service (NMFS) in the U.S. Southwest Region. The SWFSC generates the science necessary to manage and conserve the living marine resources of the California Current, the eastern tropical and north Pacific, and the Southern Ocean¹ (Figure 1). These regions span millions of square kilometers and a range of coastal, shelf, and oceanic environments. They support important commercial and recreational fisheries, a wide variety of non-extractive activities (e.g., recreational diving, whale watching), and endemic (abalone, salmon, sturgeon, rockfish) and transboundary (tunas, sharks, marine mammals and turtles) threatened and endangered living marine resources (see Tables A1-A4 in the Appendix).



The SWFSC's long-term ecosystem-based survey areas (in green) span large areas of coastal, shelf and oceanic habitat. In addition, SWFSC's long-term research efforts range from the CCAMLR treaty area around the Antarctic continent to the migratory pathways of whales in the Arctic; follow the trans-Pacific migratory pathways of fish, mammals and turtles across the North and South Pacific Oceans; and extend to turtle nesting beaches in Indonesia and the Caribbean.

Public expectations and needs associated with these ocean ecosystems are diverse and urgent, and form a set of drivers that are the basis for the SWFSC's scientific research:

- Recovery: of depleted fisheries, threatened and endangered species
- Restoration: of freshwater, estuarine, and coastal habitats
- Sustainability: of local and healthy seafood through commercial and recreational fisheries
- Multi-sector use: ecosystem-based management including humans; balance between commercial, recreational and natural and resource demands
- Freshwater: balance between direct human use and habitat for anadromous fishes
- Aquaculture: thriving and ecologically sound aquafarms
- Ocean health: mitigation of disease, marine biotoxins, low oxygen events and ocean acidification, pollutants

¹ The SWFSC's survey and study areas cover nearly 1.3 million km² in the California Current, 20 million km² in the eastern tropical Pacific, and 123,000 km² in the Antarctic. An additional 35 million km² are part of the Antarctic's CCMLAR Convention Area.

- Environmental variability: understanding and preparing for the short and long-term impact on living marine resources
- Partnerships: cooperative and cost-effective research programs with commercial and recreational fisheries and research collaborations with academic, government, commercial, and non-governmental organizations
- International treaties and obligations: strong living marine resource agreements with Mexico, Canada, and the broader suite of countries bordering the eastern tropical Pacific, the North Pacific and Southern Ocean
- Knowledge transfer: advancing science, communicating knowledge and serving data to the science community and the public
- Fiscal reality: maintaining expertise and capacity in the face of diminishing federal budgets for science and fisheries management.

The SWFSC provides the scientific basis needed to fulfill these expectations, meet these needs, and address these drivers. Research is authorized by the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), and the U.S. Antarctic Marine Living Resources (AMLR) Convention Act, as well as various international treaties and agreements, e.g., the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), the Agreement on the International Dolphin Conservation Program (AIDCP), the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC), the Convention on the International Trade in Endangered Species (CITES), and the International Convention for the Regulation of Whaling, among others (Table 1).

Table 1. Fishery management organizations, major congressional legislation, and international treaties and agreements providing mandates and authorization for SWFSC science and research activities.

Agreement on the International Dolphin Conservation Program (AIDCP)
Antarctic Marine Living Resources (US AMLR)
Coastal Zone Management Act of 1972 (CZMA)
Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR)
Convention on International Trade in Endangered Species (CITES)
Endangered Species Act of 1973 (ESA)
Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC)
Inter-American Tropical Tuna Commission (IATTC)
International Scientific Committee for Tuna and Tuna-like Species in the North Pacific (ISC)
International Whaling Commission (IWC)
IUCN Marine Turtle Specialist Group (IUCN MTSG)
Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA)

Marine Mammal Protection Act of 1972 (MMPA)
National Environmental Policy Act of 1970 (NEPA)
National Marine Sanctuaries Act of 1972 (NMSA)
Pacific Fishery Management Council (PFMC)
Pacific States Marine Fisheries Commission (PSMFC)
Western and Central Pacific Fisheries Commission (WCPFC)

This Strategic Science Plan represents the SWFSC's research plan for the next 5 years. The Plan organizes and communicates our activities in a way that illustrates the full spectrum of research under four primary Research Themes and fourteen Research Foci (Table 2), and provides guidance and transparency for decision-making within the SWFSC and NMFS/NOAA.

National Priorities for Ocean Research

NMFS is responsible for the management, conservation and protection of living marine resources within the United States Exclusive Economic Zone. NMFS also plays a supportive and advisory role in the management of living marine resources in coastal areas under state jurisdiction, provides scientific and policy leadership in the international arena, and implements international conservation and management measures as appropriate.

As one of five line offices within NOAA, NMFS strives to be responsive to NOAA's Next Generation Strategic Plan (<http://www.ppi.noaa.gov/ngsp/>). The SWFSC's research and this Strategic Science Plan are deliberately responsive to the same objectives for healthy oceans and organizational capabilities:

The 1976 Magnuson-Stevens Act (reauthorized in 2006) mandates conservation and management measures that:

- Prevent overfishing while achieving optimum yield;
- Are based on the best available scientific information;
- Manage individual stocks as a unit throughout their range, to the extent practicable;
- Promote efficiency, except that no such measure shall have economic allocation as its sole purpose;
- Provide for the sustained participation and minimization of adverse impacts to fishing communities.
- Minimize bycatch or mortality from bycatch.

1. *Improved understanding of ecosystems to inform resource management decisions;*
2. *Recovered and healthy marine and coastal species;*
3. *Healthy habitats that sustain resilient and thriving marine resources and communities;*
4. *Sustainable fisheries and safe seafood for healthy populations and vibrant communities;*

5. *An engaged and educated public with an improved capability to make scientifically informed environmental decisions;*
6. *Integrated services meeting the evolving demands of regional stakeholders;*
7. *Full and effective use of international partnerships and policy leadership to achieve NOAA's mission objectives;*
8. *Diverse and constantly evolving capabilities in NOAA's workforce;*
9. *Modern, safe, and sustainable facilities.*

Role of the Southwest Fisheries Science Center

The SWFSC's research is directly responsive to NMFS Headquarters, the West Coast Regional Office (WCRO; recently formed by the consolidation of the Southwest and Northwest Regional offices, SWRO and NWRO), Pacific Fishery Management Council (PFMC), State of California, Scientific Review Groups (SRGs), and the U.S. delegations to international regional fishery management organizations and international treaties. In addition, the SWFSC provides scientific information to other NMFS, NOAA and governmental agencies such as the U.S. Navy, the U.S. Bureau of Ocean Energy Management, the National Park Service, the U.S. Marine Mammal Commission, NOAA's National Ocean Service and National Marine Sanctuaries, NOAA's Damage assessment Remediation and Restoration Program (e.g., Deepwater Horizon Oil Spill) and NMFS's Office of Protected Resources. The SWFSC also provides scientific information to members of the fishing community (commercial, subsistence, and recreational), non-governmental environmental and technological

The 1973 Endangered Species Act recognizes that a rich natural heritage is of "esthetic, ecological, educational, recreational, and scientific value to our Nation and its people" and established both the means and mandate needed to protect and recover imperiled species and the ecosystems upon which they depend.

organizations, and the general public in support of management for more than 35 commercially important fishes, and recovery for over 109 threatened and endangered fish, marine mammal and marine turtle species on the U.S. West Coast alone (see Tables in the Appendix). More broadly, the Center works with other NMFS Science Centers and international partners to support management efforts for highly migratory and other international species, and it partners with academics at some of the nation's foremost institutions to collect, maintain, and analyze long time series and to train the next generation of the scientific workforce through mentoring, teaching, student involvement and collaboration with public, private and industry partners.

SWFSC scientists collect, compile, and analyze extensive information and data on fisheries, coastal communities, fish, invertebrate, and marine mammal and turtle species, and their food sources and important habitats, including physical and biological oceanographic components. In addition to ongoing survey and assessment activities, the SWFSC is engaged in cutting-edge research related to the use of acoustic technologies, remotely operated aerial and oceanic vehicles, manned submersibles, assessment of health and condition using photographs and skin and blubber biopsy samples, elucidation of population structure with newly-developed molecular genetics methods, understanding of foraging habits using stable isotopes, and use of animal-borne instrumentation to document habitat use and movement patterns. The SWFSC has been successful at transitioning such cutting-edge research to operations. For example, research on acoustic technologies helped to define standards for estimating the biomass of Antarctic krill that have been adopted for use by other researchers working throughout the Southern Ocean.

The scope of SWFSC's research is diverse and scientifically challenging. The California Current, a cold, eastern boundary current, is characterized by seasonal upwelling, a narrow continental shelf, low and variable freshwater input, and exceptional interannual oceanographic variability heavily influenced by the El Niño-Southern Oscillation. Many of its commercially significant fisheries experience boom-bust population cycles and, in the case of salmon, large-scale artificial propagation. In addition to commercial fisheries interests, there are significant recreational and non-extractive users of the ecosystem as well as disparate needs of constituents for fresh water, resulting in impacts on habitat for anadromous and estuary-dependent species. The SWFSC, together with the Northwest Fisheries Science Center (NWFSC), provides the scientific knowledge to inform management decisions on the stewardship of the California Current Large Marine Ecosystem (CCLME). Equally important to the SWFSC's scope is research conducted in tropical (eastern tropical Pacific) and polar (Southern Ocean) ecosystems involving a large stakeholder component represented by non-U.S. nations and multi-national agreements and conventions, and a significant transboundary component of the living marine resources for which the SWFSC is responsible.

The SWFSC is uniquely prepared to address these challenges by:

- Engaging a workforce comprised of talented and respected professionals known for their scientific integrity, productivity, collaborative approach and creativity in problem solving, and who hold numerous positions of regional, national and international leadership in their scientific fields;
- Generating NOAA's longest time series and largest scale ecosystem-based monitoring surveys in the California Current, eastern tropical Pacific and Southern Ocean. These observations provide the scientific information – from global to local scales – necessary for assessing and predicting the effects of climate change and environmental variability;
- Developing and providing web-based access to a wide variety of oceanographic and biological data. At present some 60 terabytes of data from almost 700 datasets can be accessed providing among the most powerful interfaces to major marine, atmospheric and remote sensing datasets on the web today;
- Developing advanced survey technology in acoustics, optics, and autonomous underwater and aerial platforms;
- Advancing molecular ecology studies and curating the world's largest collection of tissue from marine mammals, marine turtles, and California Current fishes;
- Pioneering innovative socio-economic solutions to transboundary and trans-national ecosystem-based fisheries management issues;
- Designing and implementing new paradigms for the management of marine mammals that are now integral to the MMPA and commonly used by NMFS managers;
- Developing an ecosystem-based management strategy for the Antarctic krill fishery that achieves the objectives of the Convention on the Conservation of Antarctic Marine Living Resources through a precautionary approach that quantifies risks associated with

The 1972 Marine Mammal Protection Act (amended in 1994) recognized marine mammals as “esthetic and recreational as well as economic” resources and was enacted in response to increasing concerns among scientists and the public that significant declines in some species of marine mammals were caused by human activities. The Act established a national policy to prevent marine mammal species and population stocks from declining beyond the point where they cease to be significant functioning elements of the ecosystems of which they are a part. The National Marine Fisheries Service is charged with protecting whales, dolphins, porpoises, seals, and sea lions.

harvesting practices and takes into account climate change as well as the needs of krill-dependent predators;

- Developing new assessment methods applicable to the many data-poor stocks that cannot be assessed with traditional methods;
- Creating tools to examine trade-offs in complex ecosystem management problems, such as balancing California's water supply, flood control, and fishery conservation needs;
- Developing innovative statistical tools for interpreting observer data and implementing appropriate management strategies based on these tools;
- Working internationally and partnering with scientists and managers from an extensive and diverse suite of international entities;
- Educating and training the next generation of marine resource scientists, managers and conservation biologists in partnership with the nation's leading marine research universities, and building capacity through collaborative research and training with scientists and students globally.

These capabilities are reflected in the SWFSC's research themes and foci summarized in Table 2 and described in the remainder of this Strategic Science Plan. An Implementation Process will accompany this Strategic Science Plan, and will outline the procedures for resource allocation, decision-making, and communication to accomplish core activities and high priority research. Although separate documents, the Implementation Process and Strategic Plan work together as guiding documents for the SWFSC.

Table 2: Fourteen major research foci for the SWFSC grouped into four themes.

Theme 1: Population assessment: Provide assessments and management advice to rebuild and sustain fisheries, fishing communities, protected species, and their ecosystems
Assess status and trends of focal species and stocks according to domestic mandates, international obligations, and management objectives, and support the PFMC and WCRO, and other national management bodies, inter-agency agreements, RFMOs and treaty obligations
Define units to conserve at the demographic (stocks) and evolutionary (species and subspecies) level
Develop next-generation assessment, bio-physical, and socio-economic models that can be used in data-poor situations, incorporate climate-productivity relationships, and ecosystem functions that result in improved management recommendations
Provide innovative approaches to bycatch mitigation, and assess and mitigate direct and indirect threats to managed species and the ecosystems on which they depend
Develop sustainable finfish and shellfish aquaculture capabilities; develop methods to evaluate environmental impacts and a comprehensive approach to the pros and cons of using forage fish in aquaculture feeds
Theme 2: Ecosystem analysis: Assess and predict how environmental changes and human activities affect ecosystems, and design new management paradigms for fisheries management and recovery of protected species
Understand climate- and species-habitat linkages and predict responses of oceanic, coast, and anadromous populations to natural and anthropogenic effects; develop habitat conservation and restoration techniques
Understand bottom-up and top-down forcing and roles of forage species as high value fisheries and the trophic base for higher level predators
Conceive and develop innovative Integrated Ecosystem Assessments and Management Strategy Evaluations to further develop ecosystem-based management approaches
Theme 3: Observations, measurements and surveys: Provide information and data to support population assessments and analyses of ecosystem variability and change
Maintain and, where feasible, expand premier climate and ecosystem observing programs, time series and remotely sensed observing systems to provide high quality data for science-based policy decisions
Collect data on life history, movements, ecology, and behavior of living marine resources to support assessments and predict population-level processes
Maintain, improve and automate data acquisition, archiving, quality control and data retrieval
Theme 4: Technological innovation and development: Improve ecosystem observations and survey methodologies through a variety of advanced technologies and sensor development
Develop new sensors, platforms, and techniques for ecosystem observation
Develop novel molecular methods to identify species, stocks, and conservation units, and assess animal and ecosystem health
Develop and deploy novel biologging methods to track animal movements, identify migratory routes and foraging areas, and to identify biological hotspots and critical habitats

Research Themes

Research Theme 1: *Population assessment: Provide assessments and management advice to rebuild and sustain fisheries, fishing communities, protected species, and their ecosystems*

Population assessment is a mandated activity for NMFS. The SWFSC provides scientific data, analysis and technical advice regarding population assessment to NMFS Headquarters, WCRO, PPMC, State of California, SRGs, and the U.S. delegations to international regional fishery management organizations and international treaties.

Research Foci for Theme 1

- ASSESS STATUS AND TRENDS OF FOCAL SPECIES AND STOCKS ACCORDING TO DOMESTIC MANDATES, INTERNATIONAL OBLIGATIONS, AND MANAGEMENT OBJECTIVES, AND SUPPORT THE PPMC AND WCRO, AND OTHER NATIONAL MANAGEMENT BODIES, INTER-AGENCY AGREEMENTS, RFMS AND TREATY OBLIGATIONS

Estimate abundance of populations relative to our mission, and maintain abundance estimates through time to fulfill requirements specified by mandates and management objectives. Understand trends in abundance through time, and place this information into a context relative to management objectives. Advance stock assessment approaches through development of innovative analytical tools and incorporation of multiple datasets (e.g., abundance, life history/vital rates, ecosystem).

Stock assessments are critical to ensuring that domestic and international fisheries and protected species are managed based on the best available scientific information. SWFSC scientists use fishery-dependent data from U.S. and international fisheries and fishery-independent data from their surveys to conduct assessments. Maintaining stock assessment activities requires resources to collect fishery-independent and dependent data, to conduct stock assessments, and to evaluate the likely biological and socioeconomic outcomes of management options.



California Current and North Pacific Ocean fishes and invertebrates. The SWFSC conducts status evaluations and stock assessments of coastal pelagic species (CPS), highly migratory species (HMS), Pacific coast groundfish and salmon, and invertebrates in the California Current and the

North Pacific Ocean (Table A1). Fish stock assessments include recommendations for overfishing levels and acceptable biological catch. These recommendations are used by the PFMF when setting total allowable catches for CPS, HMS, salmon and groundfish and are a key contributor to ensuring that U.S. west coast fisheries are managed based on the best available science. SWFSC fish stock assessments on protected salmonids, and potentially sharks, are used by the WCRO when developing regulations, issuing permits, reviewing status and conducting consultations under the ESA.

We also conduct fish stock assessments in support of U.S. participation in the Inter-American Tropical Tuna Commission (IATTC), the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), and the Western and Central Pacific Fisheries Commission (WCPFC). These analyses



include stock assessments, sensitivity studies, and development of population models. The SWFSC also monitors the abundance of the endangered white and black abalone in both the U.S. and Mexican waters. The assessments provide critical support for the WCRO and in formulating the recovery plan for white abalone and the status review team for the endangered black abalone.

California Current, ETP, and Central Pacific marine mammals. The MMPA requires annual marine mammal stock assessments for all stocks that occur regularly in U.S. waters. Our assessments (Table A2) provide information to the WCRO who evaluate the level of incidental human-caused mortality of marine mammals relative to Potential Biological Removal (PBR). Assessments of dolphin populations affected by the purse-seine fishery for yellowfin tuna in the ETP are used to set quotas for allowable incidental catch under the IDCPA. In support of the Pacific Islands Fisheries Science Center (PIFSC), we continue our assessment of Hawaii and remote Pacific Islands marine mammals (Table A3). The SWFSC shares the distribution and migratory routes of several species of marine mammals with Mexico and our scientists work closely with Mexican colleagues on a number of issues including the assessment and mitigation of shared risk factors. Our marine mammal assessments are also used by the U.S. Marine

Mammal Commission, the International Whaling Commission, the International Union for the Conservation of Nature, and the U.S. Navy, among others.

Pacific Ocean marine turtles. Marine turtle assessment activities include determining the abundance of high priority species in U.S. West Coast and adjacent waters through aerial and in-water surveys: leatherbacks in the Pacific, loggerheads in NW Mexico / Southern California, and green turtles in Southern California and the eastern Pacific (Table A3). These assessments contribute to NMFS-FWS Biological Review Teams. The SWFSC is leading efforts to develop



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metrics to assist marine turtle management and for developing an ecosystem-based framework for marine turtle stock assessments. The assessments are critical components for developing recovery strategies for endangered sea turtles and supporting existing and new international agreements to protect sea turtles.

Antarctic Living Marine Resources. The SWFSC conducts assessments of Antarctic finfishes, krill, and krill-dependent predators, e.g., pinnipeds and penguins (Table A4). These assessments are critical to the development of scientific advice that underpins Conservation Measures that the CCAMLR adopts for commercial fisheries that operate throughout the Southern Ocean.

Included are estimates of stock biomass and status and characterization of population and ecosystem dynamics. Additional datasets collected during demersal surveys are used to characterize Antarctic seabed habitats (including the species composition of invertebrate communities, bathymetry, and seabed characteristics), and physical oceanographic characteristics.



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- *DEFINE UNITS TO CONSERVE AT THE DEMOGRAPHIC (STOCKS) AND EVOLUTIONARY (SPECIES AND SUBSPECIES) LEVEL USING GENETICS, PHOTOGRAMMETRY, ACOUSTICS, AND ANIMAL MOVEMENTS*

Orcinus orca
A dominant predator

Southern Hemisphere

Northern Hemisphere

1 Killer Whale (Orcinus orca)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

2 Pacific Whitebelly (Lamna nasus)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

3 Longfins (Lamna nasus)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

4 Finback (Lamna nasus)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

5 Grappling Whale (Pseudorca crassidens)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

6 Offshore Killer Whale (Orcinus orca)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

7 Killer Whale (Orcinus orca)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

8 Type 1 Eastern North Atlantic (Orcinus orca)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

9 Subarctic Killer Whale (Orcinus orca)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

10 Type 2 Eastern North Atlantic (Orcinus orca)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

11 Humpback Whale (Megaptera novaeangliae)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

12 Minke Whale (Balaenoides borealis)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

13 Common Minke Whale (Balaenoides borealis)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

14 Humpback Whale (Megaptera novaeangliae)
• 10-12 m long
• 3-4 m high
• 3-4 m wide
• 3-4 m deep
• 3-4 m wide
• 3-4 m deep

Steelhead Bootstrap Consensus Tree

ESU Assignment:

- Klamath Mountain (Red)
- Northern California (Light Blue)
- Central California (Cyan)
- South Central California (Purple)
- Southern California (Orange)

Strict consensus of 1000 neighbor-joining trees

* 100 replicates

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Develop new analytical methods to improve assessments of fish, invertebrates, marine mammals and turtles in support of MSA, ESA, CCAMLR and MMPA missions. Incorporate ecosystem information (e.g., state of physical environment, feeding relations and variations in abundance of interacting species) into assessments. For cases where data are extremely limiting, develop new methods that provide estimates of key management benchmarks (e.g., annual catch limits) and associated estimates of uncertainty, as well as new methods for considering social and economic dimensions of resource management problems.

Implementation of the MSA, ESA, and MMPA will require development of strategies to measure and incorporate uncertainty. Several quantitative approaches are being considered in the SWFSC, including the development of (i) assessment methods that can be applied to the many stocks that have never been assessed due in large part to limited data, (ii) models that include ecosystem forcing within single species population dynamics models, and (iii) new methods that assess the interactions among populations of living marine resources, resource management, and people. The SWFSC analyzes economic and socio-cultural parameters of living marine resource utilization and provides advice for management options. These include commercial and recreational fisheries economic data collection, assessments of the economic values of resources and the sectors that harvest them, community profiles and analyses of sociocultural impacts in a number of management strategy evaluations in the California Current and in other ecosystems. We also pioneer innovative socio-economic solutions to trans-boundary and trans-national ecosystem-based fisheries management issues and provide leadership in international conservation economics. Recent efforts have also focused on cost-benefit analyses for large-scale restoration programs such as the proposed removal of four mainstem dams on the Klamath River, empirical estimation of the effects of species conservation actions on employment in the agricultural sector, and assessing the response of fishers to changes in regulations.

➤ PROVIDE INNOVATIVE APPROACHES TO BYCATCH MITIGATION AND ASSESS AND DIRECT AND INDIRECT THREATS TO MANAGED SPECIES AND THE ECOSYSTEMS ON WHICH THEY DEPEND

Mitigate bycatch. Assess direct and indirect threats. Recover depleted, threatened, and endangered species by providing science to allow for mitigation of anthropogenic impacts, and by documenting recovery.

At the SWFSC, bycatch mitigation issues can extend in unanticipated directions such as the desire to catch healthy stocks of salmon co-occurring with ESA listed stocks, the desire to provide recreational fishing opportunities for healthy stocks of rockfish while protecting depleted ones, and the desire to limit depredation by recovering pinniped and cetacean

populations that interact with a variety of fisheries. Our approaches to mitigating bycatch include developing ways to deter interactions before they occur, as well as techniques that increase post-release survival of captured animals.

Comparatively new tools such as oceanographic habitat preference models and satellite electronic tagging of three dimensional movements and water conditions, allow a comprehensive approach to lowering bycatch by allowing fishers to make decisions about where, when and at what depth to set gear in order to capture target species while eliminating encounters with bycatch species. At the same time, we develop techniques to improve post-release survival, such as the development of techniques to rapidly re-pressurize and return species to depth allowing retention of healthy stocks while limiting mortality of overfished and recovering stocks.

Threats other than direct bycatch are also serious in a number of regions for a number of taxa. For example, serious injury determination is a key component of the MMPA that is used to manage fishery takes of marine mammals in U.S. EEZ waters, and the SWFSC is heavily engaged in ongoing efforts to refine assessments of injury for marine mammals. Other indirect threats include anthropogenic noise, pollutants, marine biotoxins, ship strikes, and indirect fishery effects. The SWFSC is a leader in risk assessment, developing frameworks for identifying and mitigating these threats.

- DEVELOP SUSTAINABLE FINFISH AND SHELLFISH AQUACULTURE CAPABILITIES; DEVELOP METHODS TO EVALUATE ENVIRONMENTAL IMPACTS AND A COMPREHENSIVE APPROACH TO THE PROS AND CONS OF FORAGE FISH IN AQUACULTURE FEEDS

Develop aquaculture science approaches to meet increasing demand for seafood, support commercial and recreational fisheries and recover critically endangered species. Develop optimal diets that utilize available forage fishes as a component of artificial diets and, in partnership with a developing local algal bio-fuels industry, develop a source of algal fatty acids and proteins that mimic and can replace the nutritional characteristics of forage fishes.

A major challenge for finfish aquaculture is finding sustainable sources of feed. Short-lived forage fish can provide food for sustainable aquaculture, but left in the wild they provide a vital link to higher trophic levels. Currently the majority of California Current forage fish production is exported overseas. The SWFSC is developing integrated bio-economic models for the optimal and sustainable use of forage fishes and the economic trade-offs associated with the use of forage species (e.g., sardine and anchovy) as food for direct human consumption, food for

higher trophic level and more economically valuable fishes such as tunas or as food for cultured species.

The success of marine aquaculture rests in the hands of the private sector but the SWFSC must provide science advice for siting decisions, the monitoring of impacts of cage culture and the scientific basis for culture including the maintenance of genetic diversity, disease detection and prevention, and the quality of the seafood products. We are studying optimal diets that best utilize available forage fishes and algal fatty



acids as a component of artificial diets. Spawning, larval rearing, and grow out techniques for species such as yellowfin tuna, yellowtail and pink abalone are being conducted. This type of work also applies to the captive rearing and out-planting of threatened or endangered species such as the white abalone and coho salmon that are ESA listed. The SWFSC uses state-of-the-art genetic methods to support and improve the sustainability of Pacific salmon hatcheries and the wild populations with which they interact. Successful rearing of early life history stages also provides genetically defined material for experimental studies of maternal effects and the study of climate effects such as warming, ocean acidification and hypoxia. Finally, large-scale aquaculture can have negative effects on local environmental conditions. At the SWFSC we monitor and model the impacts of offshore cage culture on the surrounding oceans.

RESEARCH THEME 2: Ecosystem analysis: Assess and predict how environmental changes and human activities affect ecosystems, and design new management paradigms for fisheries management and recovery of protected species

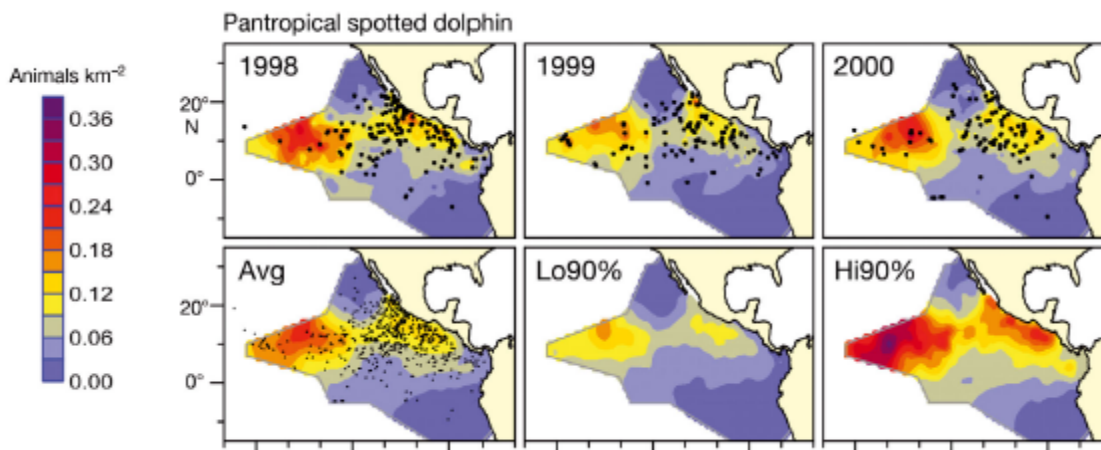
Ecosystem analysis is integral to comprehensive and proactive assessment of living marine resources. The SWFSC strives to improve the understanding of marine and coastal ecosystem structure and function in response to climate and anthropogenic forcing, to predict how such forcing affects living marine resources, and to develop and enable ecosystem approaches to management that incorporate this variability. The SWFSC evaluates physical habitat conditions and use by marine and anadromous fish, marine invertebrates, sea turtles and marine mammals, it links habitat conditions and ecological relationships to distribution and vital rates of focal species, it documents spatial patterns and temporal trends in habitat conditions, and ultimately attempts to predict how climate change will alter the distribution, abundance and productivity of focal species through effects on their habitat and interactions with other species.

Research Foci for Theme 2

- UNDERSTAND CLIMATE- AND SPECIES-HABITAT LINKAGES AND PREDICT RESPONSES OF OCEANIC, COASTAL, AND ANADROMOUS POPULATIONS TO NATURAL AND ANTHROPOGENIC EFFECTS; DEVELOP HABITAT CONSERVATION AND RESTORATION TECHNIQUES

Use historical observations, remote sensing, fisheries-dependent data, and biologging to identify and monitor change in critical habitat. Incorporate oceanographic and hydrographic data into habitat models to allow prediction of climate change effects on marine and anadromous populations. Develop lower trophic models and coupled physical-biological models, to bridge the gap between physical forcing and ecosystem structure and function.

Climate variability and change will alter the location, quality and use of critical habitat of commercially important and protected species. Next-generation assessments and ecosystem-based management both require understanding the linkages between physical habitat and biological processes. The SWFSC uses historical observations, remote sensing, fisheries-dependent data, animal tracking, and new sampling technologies to identify and monitor change in critical habitat. Areas of the SWFSC's research include pelagic marine, coastal and benthic, estuarine, freshwater, and terrestrial habitats.



Interannual variation in predicted density of spotted dolphins based on species-habitat models

Changes in pelagic habitat can greatly impact ecosystem structure and function. A combination of the Center's laboratory and field experiments together with observing programs (e.g., via programs such as the California Cooperative Oceanic Fisheries Investigations, CalCOFI), allow a balanced approach to the study of the potential for secular anthropogenic climate change against the background of natural fluctuations at various time scales. Natural fluctuations of temperature and productivity at multiple temporal scales can influence the forage base of the

apex predators. As our understanding of species-habitat linkages improves, we will be able to include these dynamics into next-generation multi-species stock assessments and ecosystem management strategies.

Ocean chemistry is an emerging area of concern with increasing ocean acidification and expanding hypoxia. The California Current, in particular, is an interesting area for researching these topics, because the physical and biological processes that define it combine to create areas of low pH and oxygen stress. This aspect of habitat impinges on benthic organisms as well as vertically migrating pelagic organisms. A combination of laboratory and field experiments together with observing programs allows a balanced approach to the study of the potential for secular anthropogenic climate change against the background of natural fluctuations at various time scales.

Ocean-freshwater-estuarine-terrestrial habitat interfaces are focal to the study of anadromous species. Pacific salmon have complex habitat requirements that must be met to complete their life cycle. The SWFSC conducts field studies and develops analytic tools to better understand the linkages between natural environmental variability, habitat processes and conditions, human activities, and the response of individuals and populations of salmon. Natural climate variability drives large fluctuations in salmon abundance, complicating management of salmon fisheries and conservation programs. Human activities tend to degrade and simplify salmon freshwater and estuarine habitats, which in turn reduces life history diversity and population resilience. Our research makes use of hydrologic, hydraulic, geomorphic and biological modeling, habitat surveys (on-the-ground/water and by remote sensing), and both traditional and new fishery techniques such as electronic tagging.



A major focus is the development of models that link the dynamics of water and salmon populations to better understand how water management and habitat restoration decisions, such as those surrounding operations of California's state and federal water project or the Bay Delta Conservation Plan, affect salmon populations that are also strongly affected by variation in terrestrial and ocean climate. This involves development, application and integration of physical and biological models. We are exploring the use of relatively traditional stage-structured population models as well as newer population modeling approaches based on integral projection methods and dynamic energy budget theory.

Another important area of inquiry is restoration of depleted or extirpated populations of salmon. Typically, habitat degradation is the ultimate cause of population problems in California watersheds, but climate variation plays a proximate role, and the resulting low population sizes have lead to inbreeding and loss of adaptive genetic variation. Successful population restoration will require simultaneous consideration and management of habitat and genetic problems and mitigation of periods of unfavorable climate conditions. We are studying the efficacy of various stream restoration strategies and how to utilize captive-reared and artificially propagated stocks, with an initial focus on endangered coho salmon in central CA and an eye towards Chinook salmon and steelhead in the Central Valley.



In benthic systems the SWFSC develops new techniques and technologies to assess the status of deep-water benthic habitats and the use of these habitats by marine species, including visual surveys using manned and unmanned submersibles, simple underwater camera and video systems, and multibeam sonar.

The SWFSC will develop advanced habitat assessment tools that can provide repeatable regional scale assessments to enable detection of responses over years to decades. This will involve a combination of site-level experimental manipulations within a landscape framework, application of various remote sensing techniques and coupled physical and biological modeling to create quantitative, regional scale maps of habitat conditions.

➤ UNDERSTAND BOTTOM-UP AND TOP-DOWN FORCINGS AND ROLES OF FORAGE SPECIES AS HIGH VALUE FISHERIES AND THE TROPHIC BASE FOR HIGHER LEVEL PREDATORS

Understand and quantify how changes driven from lower, middle, and upper trophic levels impact the pathways and fluxes of energy flow through marine ecosystems and ultimately affect the efficacies and outcomes of alternative management strategies for NMFS trust species.

Ecosystems are simultaneously forced from the bottom up (e.g., by spatial and temporal variation in primary production and the species composition of the phytoplankton), middle out (e.g., by variations in the biomasses of key forage species), and top down (e.g., by variations in predation and fishing mortality). Developing an improved

understanding of how these drivers structure ecosystems will thus provide follow-on improvements in management advice provided by the Center.

Understanding energy flow and throughput in marine ecosystems requires work that is linked to other research foci identified in this Strategic Plan and depends both on data collected in the field and on analyses and modeling conducted in the laboratory. With an improved understanding of temporal and spatial variation in ecosystem structure and function, the



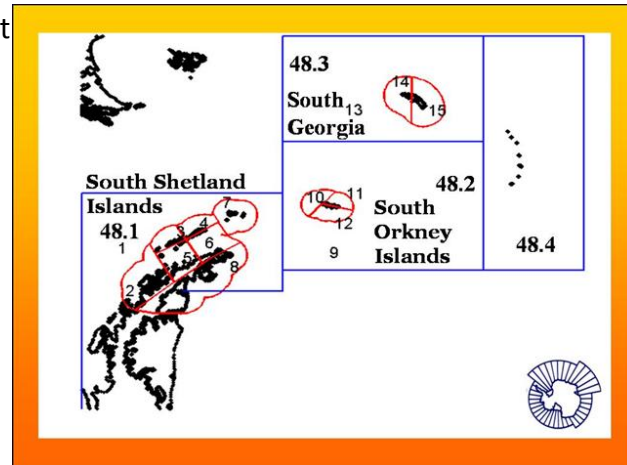
SWFSC will better predict the potential, cascading effects from fishing. We will thus be better able to address questions such as “how effective might different escapement levels for forage species be as set-asides for predators”; “what harvest rates for upper level predators might minimize the risks of trophic cascades”; and “can the species composition of fisheries removals be managed so that particular ecosystem outcomes are more likely to be achieved/avoided?”

➤ CONCEIVE AND DEVELOP INNOVATIVE INTEGRATED ECOSYSTEM ASSESSMENTS AND MANAGEMENT STRATEGY EVALUATIONS TO FURTHER DEVELOP ECOSYSTEM-BASED MANAGEMENT APPROACHES

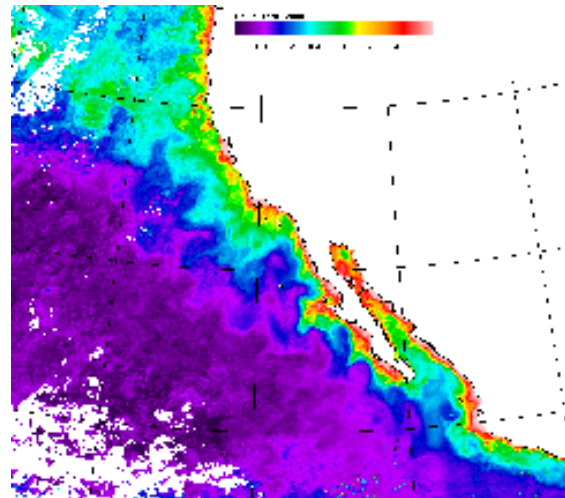
Identify key attributes of ecosystem structure and function as well as indicators of the impacts of human activities on marine ecosystems. Summarize the status and trends of key ecosystem attributes and pressures on those attributes. Quantify what natural or human pressures are influencing the status of key attributes. Evaluate how alternative management strategies and spatial plans influence different ocean-use sectors.

Ecosystem-based management and marine spatial planning efforts require an integrated, spatially explicit assessment of ecosystem status and forecast of changes in the delivery of ecosystem services under different management scenarios. Integrated Ecosystem Assessments (IEAs) are being developed to address the needs for a rigorous analysis of the cumulative impacts of ocean use and an integrated evaluation of policy options. Two focus areas in which the SWFSC is helping define ecosystem-based approaches are the AMLR Program and the California Current IEA (CCIEA).

The United States is one of 25 nations (as part of CCAMLR) that regulate fishing activities in waters surrounding the southern continent. NOAA Fisheries' U.S. Antarctic Marine Living Resources (AMLR) Program is a national program providing information needed for the development and support of U.S. policy regarding the conservation and management of the marine living resources in the ocean areas surrounding Antarctica. AMLR emphasizes directed research to manage the Antarctic marine living resources from an ecosystem perspective. To this end, the SWFSC collects the scientific information needed to detect, monitor, and predict the effects of harvesting and associated activities on target, dependent, and related species and populations of the Antarctic marine living resources and the ecosystem(s) of which they are a part.



A major focus of the SWFSC's research related to IEAs is a collaborative effort with the NWFSC in the development of the CCIEA. The ultimate aim of the CCIEA is to understand the web of interactions that link drivers/pressures (e.g., climate change, fishing, coastal zone development, aquaculture, energy development, shipping) to ecosystem components, to highlight trade-offs among different ecosystem objectives and test management scenarios and spatial plans that potentially reduce conflicts among ocean-use sectors, and to forecast how changing environmental conditions and management actions affect the status of these ecosystem components. The SWFSC currently has the lead in



developing four components of the CCIEA: Pacific salmon, coastal pelagic species, marine mammals, and climate status and trends, with a focus on evaluating ecosystem vulnerability to climate change.

RESEARCH THEME 3: *Observations, measurements and surveys: Provide information and data to support population assessments and analyses of ecosystem variability and change*

Observations, measurements, and surveys form the basis for the research conducted by the SWFSC. Time series and the data they contain create the baseline for addressing emerging issues, and for predicting future scenarios and hind-casting past patterns related to the assessment of living marine resources and ecosystem dynamics.

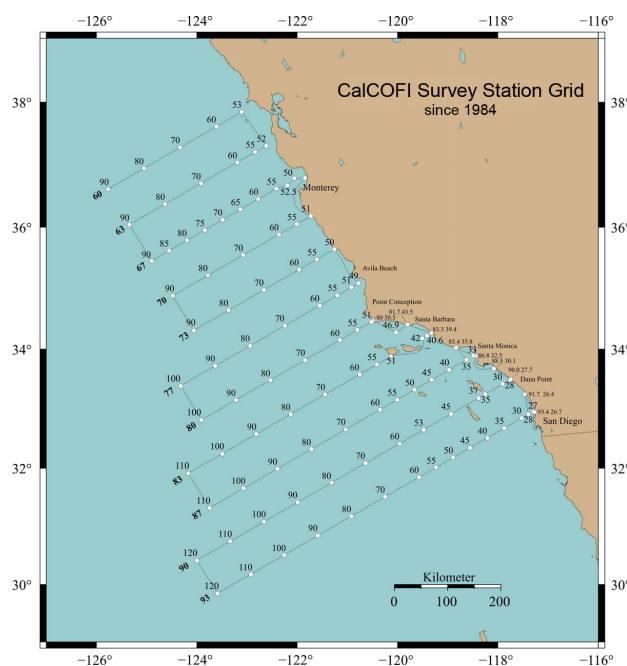
Research Foci for Theme 3

- MAINTAIN AND, WHERE FEASIBLE, EXPAND PREMIER CLIMATE AND ECOSYSTEM OBSERVING PROGRAMS, TIME SERIES AND REMOTE SENSING SYSTEMS TO PROVIDE HIGH QUALITY DATA FOR SCIENCE-BASED POLICY DECISIONS

Maintain existing time series datasets to enable assessment of status, trends, impacts of fisheries and other human activities, and emerging issues.

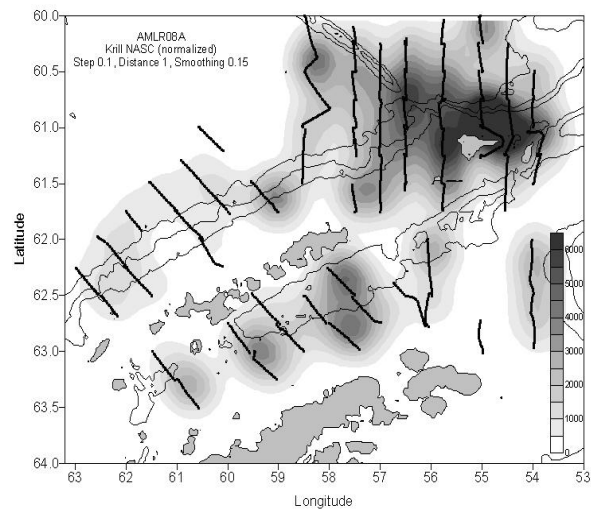
Time series form the basis not only for monitoring managed species, but also for addressing unexpected or emerging issues. The SWFSC has a long history of maintaining time series data and is a leader in incorporating ecosystem measurements into time series for abundance and trends of managed species, whether they be directly targeted or protected.

The 64-year-old California Cooperative Oceanic Fisheries Investigations (CalCOFI) are a unique partnership of NMFS, the Scripps Institution of Oceanography, and



the California Department of Fish and Game. Formed in 1949 to study the ecological aspects of the collapse of the sardine populations off California, today its focus has shifted to the study of the marine environment off the coast of California and the management of its living resources, and is among the foremost observational oceanography program in the US. CalCOFI surveys are the basis for NMFS research on the population biology of the major coastal pelagic fishes (Pacific sardine, northern anchovy, hake, Pacific mackerel, and jack mackerel) of the California Current System. A key goal is to learn how dynamic oceanographic features affect the distribution and abundance of important fish species and fish assemblages. Close collaboration with Mexican research partners in relation to their biological-oceanographic survey (IMECOCAL) is vitally important to this goal. Part of this is an extensive series of international training courses given by NMFS scientists over the past thirty years.

The SWFSC also has produced the 26-year AMLR data series (covering the area around the South Shetland Islands, Elephant Island, and the Antarctic Peninsula and including physical oceanographic observations plus ecological observations on all trophic levels from phytoplankton through krill to predators such as penguins and pinnipeds). The western Antarctic Peninsula and the surrounding ocean exhibit some of the most dynamic changes on the planet. The SWFSC's research portfolio in the Southern Ocean is the cornerstone of NOAA's mission to understand the ecological consequences of climate change in the Antarctic. Over the last 25 years Center scientists have conducted annual studies during the breeding season of penguins, seals, finfish, and their principal prey, Antarctic krill. NOAA's research via the SWFSC will help to develop rational and responsive conservation measures to ensure that the Antarctic ecosystems are protected.

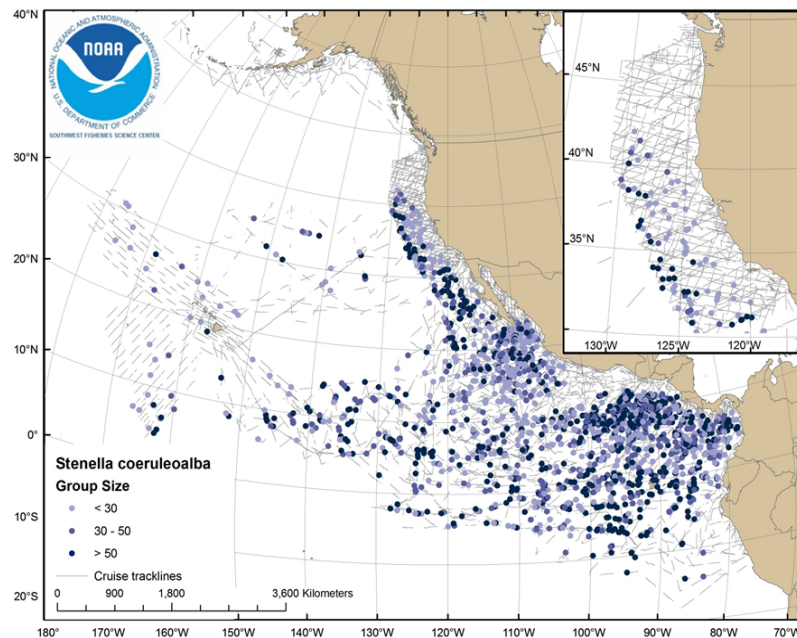


Krill density around the South Shetland Islands, western Antarctic Peninsula.

The SWFSC's marine mammal data series include long-term ship, aerial and land-based surveys of cetaceans and pinnipeds. Ship-based surveys, include the 17-year California Current data series and the 32-year eastern tropical Pacific data series include physical and biological oceanographic datasets, data on mid-trophic fishes and invertebrates, and all cetaceans, seabirds, and marine turtles in the ecosystem. SWFSC time series on California pinnipeds extends over a period of 37 years and aerial survey data series harbor porpoise for 27 years.

Land-based surveys for eastern gray whales include the 20-year productivity survey that monitors the northbound cow / calf migration from the Piedras Blancas Lighthouse. The SWFSC continues the gray whale abundance survey, which monitors the southbound migration from Granite Canyon, initiated 46 years ago by the AFSC (Alaska Fisheries Science Center). Additional long-term time series include the 31-year time series of sea lion foraging habits on the California Channel Islands (that includes abundances of prey items over time, enabling fine-scale correlations with oceanographic conditions); and in southern California, small-boat surveys of bottlenose dolphins distribution, monitoring of sea turtles in San Diego Bay (23 years) abundance and individual identification (26 years) and records of marine mammal strandings (40 years).

The SWFSC continues to lead nationally and internationally in the development of ship- and aerial-based visual survey methodology, the incorporation of multi-trophic level data collection to address ecosystem questions and has pioneered the use of acoustic methods in cetacean surveys. These data series provide the basis for sound management decisions, for the mitigation of current threats and for recovery both nationally and in international arenas.



Striped dolphin sightings collected on SWFSC cetacean surveys.

The SWFSC has also produced the 31-year California Current juvenile rockfish trawl survey data series. The surveyed species include pelagic young-of-the-year rockfish, other groundfish (post ichthyoplanktonic stage prior to settlement), and micronektonic species (coastal pelagics, mesopelagics, gelatinous zooplankton, krill), as well as hydrography, seabird and mammal observations and, multibeam sonar data. Since 2004 the survey area has included the entire region of the U.S. EEZ south of Cape Mendocino, and a companion survey is conducted in northern waters by the NWFSC with comparable gear and methods. Additional SWFSC time series include the 20-year time series on essential fish habitat for West Coast demersal fish

assemblages and macro-invertebrates (including coral communities) in deep water using a variety of methods and the 20-year time series of juvenile steelhead status and growth in Soquel Creek, CA, in collaboration with the Soquel Demonstration State Forest.

➤ COLLECT DATA ON LIFE HISTORY, MOVEMENTS, ECOLOGY, AND BEHAVIOR OF LIVING MARINE RESOURCES TO SUPPORT ASSESSMENTS AND PREDICT POPULATION-LEVEL RESPONSES

Collect pre-recruit finfish data to support fishery stock assessments. Obtain, and maintain current, estimates of demographic parameters and monitor condition and health. Maximize information obtained from skin and blubber biopsy samples collected from live animals, with a specific focus on genetics, hormones and stable isotopes. Increase capabilities to obtain ecological, including movement, data using biologging technology.

In addition to abundance surveys that feed directly into stock assessments, the SWFSC collects data on a variety of additional biological parameters of managed species that are directly relevant to population-level parameters. For example, since 1983, the Center has conducted a rockfish pre-recruit survey in May and June off central California. The resulting index of recruitment is used in a number of groundfish assessments, giving an indication of strong recruitment



events several years before the recruits appear in the fishery. Surveys of juvenile salmon in San Francisco Bay and the Gulf of the Farallones have documented strong size-dependent mortality of young-of-the-year salmon during periods of poor ocean conditions, suggesting the potential of such surveys to inform forecasts of salmon abundance used in ocean fishery management. Krill abundance surveys around the Antarctic's Shetland Islands support an allocation scheme to divide the krill catch limit among Small Scale Management Units. The SWFSC's acoustic and visual surveys in the ETP are the basis for MMPA assessments of dolphins. We participate in the CalCOFI surveys that generate abundance information used in stock assessments of coastal pelagic species. Not all survey work done at the SWFSC is currently used in formal stock assessments. A near-term focus will be investigating the potential utility of data from these surveys in stock assessments, and identification of improvements to the surveys that would be needed to make them usable, if they are currently not.

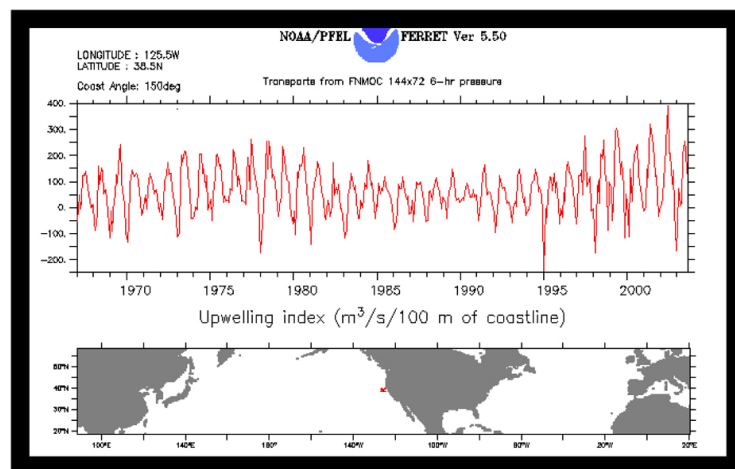
➤ MAINTAIN, IMPROVE AND AUTOMATE DATA ACQUISITION, ARCHIVING, QUALITY CONTROL AND DATA RETRIEVAL

Work with NMFS, NOAA and multi-agency efforts to define data content, metadata, search, and transport standards. Add datasets to better meet changing Center, NMFS and NOAA program priorities. Work on improving the datasets, including efforts to improve data estimation. Develop new and/or improved indices and derived products from the data to better meet changing program priorities. Develop new and/or improved data services for greater interoperability with NOAA, NMFS, GEOSS and other data management and integration activities. Develop new and/or improved scripts, plugins, apps and web pages to make the process of finding, subsetting and obtaining the data seamless to the scientist, manager or web developer from within the applications of their choice.

Access to a wide variety of distributed data underlies our ability to carry out IEAs, habitat assessment and modeling, and managing endangered and protected species. These distributed datasets may include satellite data, *in situ* oceanographic data, and baseline biological data, and the user must be able to access and combine in a seamless fashion. The importance of NOAA data to the agency, and the need for these types of standards is recognized in a variety of NOAA and NMFS Directives, including EDMC Directives, GEO-IDE Guidelines, and NMFS Guidelines.

SWFSC has been at the forefront of these developments in data management and distribution, handling over 60 terabytes of data representing almost 700 datasets, with the numbers expected to grow rapidly in the next few years. These data are readily available to researchers and managers using mechanisms that follow national standards.

The datasets are used internationally by federal, state, local and foreign governments, and by academic researchers, NGOs, fishers and students among others. Presently, there are on average one million data requests a day from over 20,000 unique users a month. Emphasis is on support for fishers, support for CCIEA development, for protected species research and management decision support, for salmon decision support systems, and for the ocean acidification program. Our data management and distribution efforts are unique, but complementary to, the efforts of the various NOAA and Navy forecast and archive centers.



Live Access Server
Global Upwelling Index

RESEARCH THEME 4: *Technological innovation and development: Improve ecosystem observations and survey methodologies through a variety of advanced technologies and sensor development*

Technological innovation and development is essential to cutting-edge science and a hallmark of the SWFSC. With its state-of-the-art facilities the SWFSC will play a key role within NOAA/NMFS to create the next generation of technologies needed to improve effectiveness of surveys, characterize populations, observe the ecosystem, and provide improved assessments. With the opening of the Ocean Technology Development Test Tank, SWFSC will foster new collaborations with academic, industry and government scientists and engineers; the “Tech Tank” will provide opportunities for technology testing, technology outreach, technology transfer and public-private partnerships.

Research Foci for Theme 4

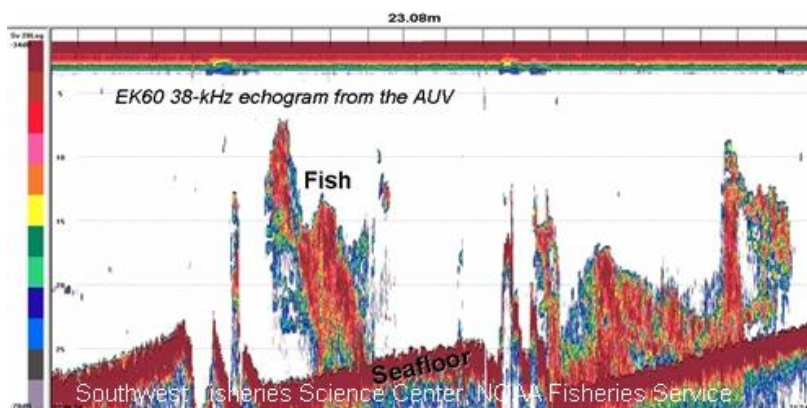
➤ DEVELOP NEW SENSORS, PLATFORMS AND TECHNIQUES FOR ECOSYSTEM OBSERVATION

Develop new or innovative uses of sampling technologies. Characterize measurements and sampling uncertainties, and define gaps in existing data. Develop, refine, and employ advanced survey technologies to improve the accuracy, precision and efficiency of fisheries surveys and resulting stock assessments. Conduct fisheries research and surveys using the instrumentation and methods developed.

Traditional fishery-independent survey methods are insufficient to meet the needs of improved stock assessments. Available ship time is insufficient to tow as many nets as needed, and many important areas cannot be sampled with nets because of their structural complexity.

The SWFSC is developing new survey methods to better sample untrawlable habitats, expand the quantity and quality of

information that can be acquired from ships, and pursuing other survey methods that do not require ships. These include use of LiDAR, satellite remote sensing, manned and unmanned submersibles and aerial platforms, instrumented buoys, novel applications of state-of-the-art



multifrequency, sidescan, and multibeam sonars and acoustic Doppler current profilers, a novel towed stereo-camera system [Advanced Survey Technologies' (AST's) FasTowCam] for validating the acoustic classifications, and a broad-bandwidth multi-scattering hyperbaric tank for measuring acoustic signatures of various species. The SWFSC develops methods and models for improving the science and management of living marine resources. For example, the AST Program has developed: a technique for using ADCPs (Acoustic Doppler Current Profilers) to measure the three-dimensional (3D) velocities of marine organisms; a model for krill target strength (TS) which was adopted as the international standard; a procedure for quantifying total error (random and systematic components of measurement and sampling error) in acoustic surveys; and a versatile multiscattering technique. This technique can be used for: quantifying fish and zooplankton and their behaviors and growth rates in tanks; measuring their broad bandwidth sound scattering and absorption spectra ('acoustic signatures'); and, incidentally, acoustically measuring the numbers and sizes of humans in a room, and their amount of clothing. We continue to work on the development of multiple powerful techniques based on Multifrequency Biplanar Interferometry (MBI) for greatly improved 3D imaging and classifications of fish and seabed.



➤ DEVELOP NOVEL MOLECULAR METHODS TO IDENTIFY SPECIES, STOCKS, AND CONSERVATION UNITS, AND ASSESS ANIMAL AND ECOSYSTEM HEALTH

Continue to develop new molecular markers and laboratory and analytical tools for defining management units relevant to our mandates.

In order to effectively manage species, biologically relevant units must be defined. The SWFSC provides sound and relevant scientific guidance to the Pacific Fisheries Management Council on issues pertaining to CPS, HMS and anadromous species (Salmon) and on marine mammal and marine turtles under the MMPA and ESA. Our activities focus primarily on the application of genetics and biotechnology to define management units, address taxonomic issues, study life history parameters, and improve existing survey methodologies, and we apply a suite of tools including analyses of mitochondrial and nuclear DNA polymorphism, otolith microchemistry, stable isotopes, and physiology to identify demographically independent populations. These tools are currently being applied to studies of Pacific Sardine, Northern Anchovy, Shortfin Mako

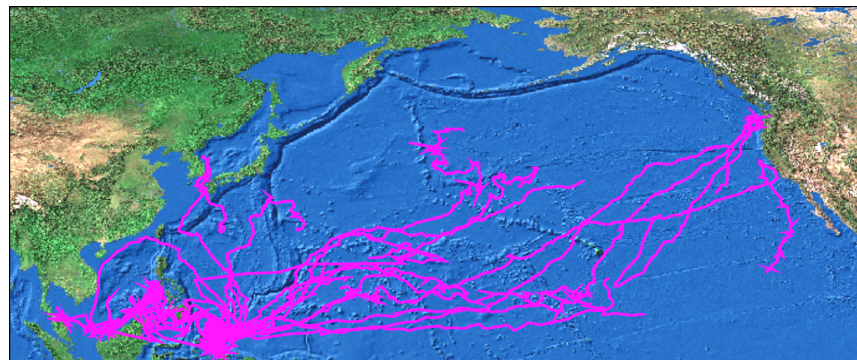
Shark, Common Thresher Shark, Silky Shark, Swordfish, Albacore, Pacific salmon, and numerous groundfish species, as well as marine mammals and marine turtles.

- DEVELOP NOVEL BIOLOGGING METHODS TO IDENTIFY MOVEMENT, MIGRATORY ROUTES AND DISPERSAL PATTERNS AND TO IDENTIFY HOTSPOTS/CRITICAL HABITAT

Develop and use biologging technology to extend the Center's ability to identify migratory routes and breeding and feeding grounds for free-ranging, highly migratory species of fish, marine turtles and marine mammals in support of management.

Biologging, including satellite and acoustic telemetry, uses miniaturized animal-attached tags for collecting and relaying data about an individual's movements, behavior, and the surrounding environment. The SWFSC uses satellite telemetry to discover the migratory routes of leatherback sea

turtles as they transit the Pacific Ocean from foraging grounds along the U.S. West Coast to nesting beaches in Indonesia and to identify the depth at which turtles feed to design dynamic management measures



Satellite tracks of leatherback turtles illustrate their movements from nesting beaches in Indonesia to foraging regions in the California Current.

for the swordfish fishery. Satellite telemetry has been used on olive ridley and green sea turtles to identify foraging habitat in the eastern tropical Pacific and on a fine scale, in San Diego Bay. The application of satellite telemetry on marine mammals includes studies of deep-diving cetaceans and their response to naval sonar (Bahamas), killer whales to distinguish foraging preferences and movements of ecotypes, Antarctic minke whales and eastern Pacific gray whales.

In freshwater and estuarine habitats, SWFSC is using the latest generation of acoustic tags and receivers to monitor migratory behavior and survival of various wild and hatchery runs of Chinook salmon in the Sacramento River to document patterns in survival and infer causes of high mortality in the river, delta, and bays. We are combining these studies with tagging of predators such as striped bass to understand how predators use man-made structures such as large water diversion screen facilities to prey upon migrating salmon. Acoustic tags are also being used to study how ocean wave energy installations affect migrating green sturgeon in the

coastal ocean. Data from telemetry studies are used in population dynamics models and in habitat models that can guide consultations on essential fish habitat and critical habitat.

Research Infrastructure and Support

SWFSC research activities require the active development and improvement of the Center's infrastructure and support capabilities. This section briefly describes the tools, facilities, and support staff needed to enable high-priority research.

➤ INFRASTRUCTURE: THE SWFSC MAINTAINS THE INFRASTRUCTURE FOR LABORATORY FACILITIES, FIELD SAMPLING, CRITICAL DATA MANAGEMENT FUNCTIONS, AND ADMINISTRATIVE ACTIVITIES

Building, office, laboratory, and library facilities and seawater systems are required to achieve research goals. The SWFSC maintains several facilities that are required to support research in La Jolla, Pacific Grove, Santa Cruz, and Granite Canyon, California. We will seek additional funding to maintain and expand this functionality including the build-out of the third wing of the Santa Cruz Laboratory. The foundation of for the third wing was laid down at the time of the Lab's construction, but funding limitations did not allow its completion. With expanded activities of the Laboratory in the Central Valley salmon recovery, the space will be needed to accommodate laboratories and personnel who are already in a compressed state.

The new SWFSC Laboratory in La Jolla, occupied in winter of 2013, houses 33 state-of-the-art laboratories; experimental aquaria; a main library and extensive research collections. The new facility will allow NOAA to create the next generation of technologies essential for achieving its current and future missions. It will also enhance collaborations with the community of scientists, both locally, at Scripps Inst. of Oceanography together with the timely completion of their Marine Ecosystem Sensing, Observation and Modeling (MESOM) building, and around the globe, to develop the next generation of fisheries and oceanographic instrumentation.

The new La Jolla Lab will incorporate a large state of the art sea- and fresh-water "Tech Tank". This world-class facility will expand NOAA's ability to develop and apply advanced technologies for surveys of fisheries resources and their associated ecosystems and to foster collaborations on fisheries management issues. The Tech Tank will provide a controlled environment to develop, test, and calibrate new technologies before deploying them on routine surveys or at remote locations at sea. With the Tech Tank, the SWFSC will continue its pioneering work in the development and use of acoustical and optical technologies for non-lethal surveys of protected and managed species (mammals, fishes and turtles) and for the detection of near-surface fish schools (such as sardine) during ship-based surveys. The Tech Tank is of sufficient size (10m wide by 20m long by 10m deep) to calibrate and test a wide variety of instruments

with minimal boundary effects. Water conditions can be controlled over a broad range of temperatures and salinities and the tank would be able to accommodate living marine animals. Examples of experiments that could be performed in the tank include: calibration and performance testing of transducer and hydrophone arrays; testing of underwater cameras, strobe and laser systems; testing of gliders, autonomous underwater vehicles, floats, drifters, untethered profilers, ROVs, tags and fishing nets; and characterization of the behavior of marine animals and their response to remote sensors. These capabilities will support scientists developing advanced survey technologies throughout NMFS and NOAA, as well as instrument developers from other national academic and government institutions. The Tech Tank will provide exciting new opportunities for working with a broad range of maritime technology industries, including and beyond the fishery sector. The Tech Tank will promote technology testing, technology outreach, technology transfer and public-private partnerships with regional, national and international maritime industries.



Artist's rendition of the Tech Tank (bottom right of schematic).

The SWFSC has a suite of state-of the art genetics facilities, at the La Jolla and Santa Cruz laboratories, including a clean room for ancient DNA, dedicated pre-PCR rooms, robotic liquid handling for PCR set-up, and instruments for real-time quantitative PCR, fluorescent DNA quantification, microsatellite and SNP genotyping, and DNA sequencing by capillary electrophoresis. The two facilities also have newly designed chemistry labs support stable isotope and hormone studies.

The Santa Cruz Laboratory has a research aquarium facility, with flow-through seawater and recirculating freshwater supplies. A variety of tanks and two artificial stream channels are available, as well as four large salt-water circular tanks used for rearing captive-bred coho salmon from the smolt stage to maturity. The coho captive broodstock program also makes use of the Kingfisher Flat hatchery operated by the Monterey Bay Salmon and Trout Project in Santa

Cruz County, and CA Department of Fish and Wildlife's Warm Springs Hatchery in Sonoma County.

The SWFSC maintains research stations at Granite Canyon on the central California coast and two research stations which are occupied annually from October – March on Cape Shirreff, Livingston Island and Admiralty Bay on King George Island in the South Shetlands, Antarctica.

The SWFSC owns and operates a fleet of small boats necessary for nearshore and riverine research activities. We also rely on both NOAA and chartered commercial vessels and aircraft to complete mission critical fieldwork. The SWFSC is committed to maintaining and expanding the functionality and available operational days of these NOAA ships and aircraft by continuing to work closely with NOAA's Office of Marine and Aviation Operations and by working with the commercial community to retain access to and use of chartered ships and aircraft.

The SWFSC curates the largest global collection of marine mammal and turtle tissue for molecular studies. The collection of approximately 130,000 samples distributed globally represents almost all species and populations; its spatial, temporal and taxonomic breadth allows timely response to management needs. The SWFSC also maintains a comprehensive collection of tissues (>187,000 individuals) from Pacific salmon and rockfish populations in California and southern Oregon, and contributes to the coast-wide baseline dataset used for genetic stock identification for salmon fisheries. We also curate one of the foremost ichthyoplankton collections in the world. The laboratory houses over 500,000 vials with specimens collected primarily in the California Current and eastern tropical Pacific. The collection provides support to fish stock assessments, provide fishery-independent time series information and support the investigation of environmental variability and climate change in the region. The data management responsibilities of the SWFSC are complex and must be supported to ensure that data and data products are high quality, accessible, and released in a manner consistent with applicable laws and policies. The SWFSC must have the capacity to archive, compile and interrelate, model, and analyze numerous independent data types totaling millions of records. We must maintain and expand the documentation of metadata and other data management requirements.

The continuation of present services, as well as of any planned future development of the datasets and services, are critically dependent on maintaining the present staff, and maintaining both the staff and equipment in an environment where innovation and creativity are fostered.

Education and Capacity Building

The SWFSC partners in the education and training of the next generation of marine resource scientists, managers and conservation biologists with the nation's leading marine research universities, including Scripps Institution of Oceanography at UC San Diego, UC Santa Cruz and the Naval Postgraduate school. A founding partner in the Center for Marine Biodiversity and Conservation, the SWFSC is an innovator in interdisciplinary graduate education and training. Internationally, we extend opportunities for capacity building through collaborative research and training with scientists and students from the global marine community. The Center for Stock Assessment Research (CSTAR), in collaboration with UCSC, and the nascent Center for the Advancement of Population Assessment Methodology (CAPAM) in collaboration with SWFSC, Scripps and IATTC researchers train stock assessment scientists, many of who end up working at NMFS. The SWFSC is devoted to increasing diversity in marine science and has participated in many initiatives to improve opportunities for graduate work in the field, including hosting symposia at the annual conferences of the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS). On primarily a volunteer basis, staff at the SWFSC develop and/or participate in a wide variety of creative outreach, public and educational activities designed to promote STEM (science, technology, engineering and math) education.

Support staff

The SWFSC research activities require dedicated and knowledgeable technical and support staff to design, prepare, stage, and maintain critical equipment and instruments and facilities. We must continue to dedicate staff and budgetary resources for operations and administrative functions. Continued information technology support is critical to ensure computer systems are secure and functional and to develop and maintain necessary databases and applications for research and administrative functions. Laboratory, field, and office safety is a priority and an essential part of successful performance of the Center's research. Staff with expertise and resources to maintain our facilities and ensure workplace safety and environmental compliance is critical support functions that must be supported. Finally, our communications staff provides publication, web, graphics, outreach, and education services to promote and support effective communications of our scientific research activities and findings to a broad audience.

Implementation strategy

Accompanying the Strategic Science Plan will be an Implementation Process, outlining the processes for resource allocation decision-making and communication to accomplish core activities and high priority research. While separate documents, the Implementation Process and Strategic Science Plan will work together as guiding documents for the Center.

Appendix. Tables of species, species groups and stocks regularly assessed by the SWFSC

A1. Table of fish and shellfish species and species groups regularly assessed by the SWFSC within the U.S. Exclusive Economic Zone off California

A2. Table of pinniped, cetacean and turtle species and species groups regularly assessed by SWFSC within the U.S. Exclusive Economic Zone off California.

A3. Table of marine mammals and turtles assessed by the SWFSC in the Pacific Ocean outside the U.S. EEZ.

A4. Table of species and stocks for which the SWFSC regularly provides management advice to the CCAMLR. Geographical areas identify sectors of the Southern Ocean (e.g., “Atlantic” identifies the Atlantic sector); “circumpolar” identifies cases where advice is provided for all three sectors of the Southern Ocean (Atlantic, Indian, and Pacific).

A1. Table of fish and shellfish species and species groups regularly assessed by the SWFSC within the U.S. Exclusive Economic Zone off California

Common Name	Stock	SAIP Tier	Threatened/ Endangered/ Depleted
Abalone, Black	Pacific Ocean, coastal areas of Mexico, CA	1	E
Abalone, White	Pacific Ocean, coastal areas of Mexico, CA	1	T
Albacore	North Pacific	2	
Bigeye Tuna	Eastern Tropical Pacific		
Black Rockfish	Northern Pacific Coast		
Blackgill Rockfish	Southern California		
Blue Rockfish	California		
Blue Shark	North Pacific Ocean		
Boccacio	Southern Pacific Coast		
Chilipepper Rockfish	Southern Pacific Coast		
Common Thresher Shark	Eastern North Pacific Ocean		
Cowcod	Southern California		
Green Sturgeon	Southern DPS	1	T
Greenspotten Rockfish	Pacific Coast		
Jack Mackerel	Pacific Coast	1	
Krill (prohibited species)	Pacific Coast		
Market Squid	Pacific Coast	1	
Northern Anchovy	Southern Pacific Coast	1	
Northern Anchovy	Northern Pacific Coast	1	
Pacific Bluefin Tuna	North Pacific	2	
Pacific Chub Mackerel	Pacific Coast		
Pacific San Dab	Pacific Coast		
Pacific Sardine	Pacific Coast	2	
Salmon, Chinook	Central Valley spring-run ESU	2	T
Salmon, Chinook	California coastal ESU	1	T
Salmon, Chinook	Sacramento River winter-run ESU	2	E
Salmon, Chinook	Sacramento River fall		
Salmon, Chinook	Klamath River fall		
Salmon, Coho	Central California Coast	1	E
Salmon, Coho	Southern Oregon/Northern California Coast ESU	1	T
Shortbelly Rockfish	Pacific Coast		
Shortfin Mako Shark	North Pacific Ocean		
Skipjack Tuna	Eastern Tropical Pacific	2	
Steelhead	Central California Coast ESU	1	T
Steelhead	Central Valley, California ESU	1	T
Steelhead	Nothern California ESU	1	T
Steelhead	South-Central California ESU	1	T
Steelhead	Southern California ESU	1	E
Striped Marlin	Eastern Tropical Pacific		
Yellowfin Tuna	Eastern Tropical Pacific		
Widow Rockfish	Pacific Coast		

A2. Table of pinniped, cetacean and turtle species and species groups regularly assessed by the SWFSC within the U.S. Exclusive Economic Zone off California.

Common Name	Stock	SAIP Tier	Threatened/ Endangered/ Depleted
Bairds beaked whale	California/Oregon/Washington	1	
Blue whale	Eastern North Pacific	2	E
Bottlenose dolphin	California Coastal	2	
Bottlenose dolphin	California/Oregon/Washington Offshore	1	
California sea lion	U.S.	2	
Cuviers beaked whale	California/Oregon/Washington	1	
Dall's porpoise	California/Oregon/Washington	2	
Dwarf Sperm Whale	California/Oregon/Washington	1	
Fin whale	California/Oregon/Washington	1	E
Gray whale	Eastern North Pacific		
Guadalupe fur seal	Mexico - Southern California	1	
Harbor porpoise	Monterey Bay	1	
Harbor porpoise	Morro Bay	2	
Harbor porpoise	Northern CA-Southern OR	2	
Harbor porpoise	San Francisco-Russian River	2	
Harbor seal	California	2	
Humpback whale	California/Oregon/Washington	2	
Humpback whale	Eastern North Pacific	2	E
Humpback whale	American Samoa	2	
Killer whale	Eastern North Pacific Offshore	1	
Long-beaked common dolphin	California	1	
Mesoplodont beaked whale	California/Oregon/Washington	1	
Minke whale	California/Oregon/Washington	1	
Northern elephant seal	California Breeding	1	
Northern right whale dolphin	California/Oregon/Washington	2	
Pacific white sided dolphin	California/Oregon/Washington - Northern and	2	
Pygmy sperm whale	California/Oregon/Washington	2	
Rissos dolphin	California/Oregon/Washington	1	
Sea Turtle, green	Southern Californai foraging population	1	E
Sea Turtle, leatherback	U.S. Pacific	1	E
Sea Turtle, loggerhead	U.S. Pacific	1	E
Sea turtle, loggerhead (foraging areas)	Pacific Ocean, nesting colonies in Japan and Australia. foraging areas in Pacific high seas and coastal areas of Eastern Pacific	1	E
Sei whale	Eastern North Pacific	1	E
Short-beaked common dolphin	California/Oregon/Washington	2	
Shortfinned pilot whale	California/Oregon/Washington	1	
Sperm whale	California/Oregon/Washington	1	E
Striped dolphin	California/Oregon/Washington	1	

A3. Table of marine mammals and turtles assessed by the SWFSC in the Pacific Ocean outside the U.S. EEZ.

Common Name	Stock	SAIP Tier	Threatened/ Endangered/ Depleted
Common dolphin	Central	1	
Common dolphin	Northern	1	
Common dolphin	Southern	1	
Spinner dolphin	Eastern	2	
Spinner dolphin	Whitebelly	2	
Spotted dolphin	Coastal	1	
Spotted dolphin	Northeastern	2	
Spotted dolphin	Western/Southern	1	
Sea Turtle, green (Breeding colonies)	Breeding colony: FL and Pacific Mexico	1	E
Sea Turtle, green	ETP	1	
Sea Turtle, green	Circumglobal tropical and temperate seas and oceans. Listed as threatened except breeding colony populations in FL and on Pacific coast of Mexico	1	T
Sea Turtle, hawksbill	Tropical seas	1	
Sea Turtle, hawksbill	ETP	1	
Sea Turtle, leatherback	Tropical, temperate, and subpolar seas	2	E
Sea Turtle, loggerhead	Tropical, temperate, and subpolar seas	1	
Sea Turtle, olive ridley	Circumglobal in tropical and temperate seas and oceans. Listed as threatened except breeding colony populations on Pacific coast of Mexico	1	T
Sea Turtle, olive ridley	Breeding colony: Pacific Mexico	1	
Sea Turtle, olive ridley (Breeding colony populations)	Breeding colony: Pacific Mexico	1	E
Vaquita	Northern Gulf of California		E

A4. Table of species and stocks for which the SWFSC regularly provides management advice to the CCAMLR. Geographical areas identify sectors of the Southern Ocean (e.g., “Atlantic” identifies the Atlantic sector); “circumpolar” identifies cases where advice is provided for all three sectors of the Southern Ocean (Atlantic, Indian, and Pacific).

Common name	Geographical areas
Invertebrates	
Antarctic krill	Atlantic, Indian
Crabs (2 primary spp.)	Atlantic
Other benthic invertebrates (e.g., habitat-fo	Circumpolar
Fishes	
Antarctic toothfish	Circumpolar
Blackfin icefish	Atlantic
Grey rockcod	Atlantic, Indian
Humped rockcod	Atlantic
Mackerel icefish	Atlantic, Indian
Marbled rockcod	Atlantic
Patagonian toothfish	Circumpolar
South Georgia icefish	Atlantic
Yellowfin notothen	Atlantic
Other fishes (e.g., Antarctic silverfish, black	Circumpolar
Pinnipeds	
Antarctic fur seal	Atlantic, Indian
Leopard seal	Atlantic
Weddell seal	Circumpolar
Seabirds	
Adélie penguin	Circumpolar
Chinstrap penguin	Atlantic
Emperor penguin	Indian, Pacific
Gentoo penguin	Atlantic
Other seabirds (e.g., albatrosses and petrels	Circumpolar